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International Journal of Current Research
Vol. 8, Issue, 12, pp.44212-44216, December, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

INVESTIGATION OF STRESS-DEFORMED STATE OF COATED HYDROCYLINDERS, EXPOSED TO PRESSURE AND TEMPERATURE CHANGES

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ARTICLE INFO

Article History:
Received 12th September, 2016
Received in revised form
09th October, 2016
Accepted 17th November, 2016
Published online 30th December, 2016

Key words:

Hydraulic cylinder,
Pressure,
Temperature,
Deformation,
Voltage.

ABSTRACT

The aim of the task is to study the stress-strain state cylinders coated bulky devices subjected to the joint action of pressure and temperature changes during operation.
The published papers in this problem the combined effect of the external pressure and temperature differential cylinder coated bulky devices are not considered. In this task, the system consists of a cylinder main relatively thick cylinder and a thin inner coating of another material such as a cylinder is subjected to external pressure and asymmetrical temperature field.

- Assume that the material of the base layer, the cylinder cover and elastic-plastic, obeys the yield condition, ie, Mises condition.
- Also, the temperature is uniformly distributed over the coating thickness, and equal to the temperature inside the main cylinder surface layer.

Since the problem relates to the definition of thermal stress field of elastic stresses and displacements of the cylinder defined by the equation of thermoelasticity theory. These equations are written separately to the cylinder and the coating is then co-solution of the equations are carried out in two conditions:

- The continuity of the radial displacement of the contact surface;
- The balance of power in the main voltage.

In conclusion, it can be shown that the effect of the coating is reduced to a certain increase in the area of adaptability. In quantitative terms, this increase depends on the physico-mechanical properties of the material and the nature of the temperature.

Citation: Mammadov Vaif Talıb, Akhmedov Alihikmat Sltanali and Aslanov Jamaladdin Nuraddin, 2016. "Investigation of stress-deformed state of coated hydrocylinders, exposed to pressure and temperature changes", *International Journal of Current Research*, 8, (12), 44212-44216.

INTRODUCTION

The article considers research of stress-strain condition of the coated cylinders, subjected to pressure and temperature changes. For this purpose used equation of thermo elasticity for elastic-plastic condition. Thermal stress and temperature distribution in the hydraulic cylinder system is defined: the basic cylinder coating (cylindrical ring) The coated hydraulic cylinder of the volumetric apparatus during the operation subjected to external pressure and temperature drop. Therefore, on the surface of the dual layer cylinder arises difficult stress-strain state. Joint action of pressure and temperature in the hydraulic cylinder system is not examined to this day. We consider the two-layer cylindrical surface of the hydraulic cylinder consisting of a relatively thick base layer and a thin inner coating of a different material (Fig. 1). The cylinder is under pressure P0 and asymmetric temperature of the field T0.

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The pressure of layer on the cylinder is denoted by P*. It is assumed that the materials of base layer and coating perfectly elastic-plastic, obey yield condition. The minimum yield point σ_{yie} and the coefficients of temperature expansion of αcylinder and coating we consider heterogeneous. We will assume that the temperature is uniformly distributed throughout the coating thickness and is equal to the temperature of the inner surface of base layer. Let $R_{inn}R_{ext}$ andRнar- internal and external (outer) radii of the base layer; δ - coating thickness. The parameters of the base layer are indicated by an index - δ, and coating characteristics – with c. We assume that αc>αδ.. As is known that the field of stresses and displacements in an elastic body (cylinder) are determined by formulas.

$$\frac{E_\delta U_\delta}{1+\nu_\delta} = \frac{E_\delta \alpha_\delta}{(1-\nu_\delta)\cdot r^2}\cdot \int_{R_{\text{вн}}}^{R_{\text{н}}} T\,(r) r dr + \frac{E_\delta \alpha_\delta}{2(1-\nu_\delta)} \cdot \left[(1-2\nu_\delta)r + \frac{R_{\text{вн}}^2}{r^2}\right] T_s$$

$$+\frac{P^*P_{вн}^2}{R_н^2-R_{вн}^2}\left[(1-2\nu_\delta)r+\frac{R_н^2}{r^2}\right]-\frac{P_oR_н^2}{R_н^2-R_{вн}^2}\left[(1-2\nu_\delta)r+\frac{R_{вн}^2}{r^2}\right]-\frac{E_\delta\cdot U_\delta\cdot\varepsilon_z\cdot r}{(1+\nu_\delta)}\ ; \qquad (1)$$

Radial Voltage:

$$\sigma_r=\frac{E_\delta\alpha_\delta}{(1-\nu_\delta)\cdot r^2}\cdot\int_{R_{вн}}^{R_н}T(r)rdr+\frac{E_\delta\alpha_\delta}{2(1-\nu_\delta)}\cdot\left(1-\frac{R_{вн}^2}{r^2}\right)\cdot T_s+\frac{P^*R_{вн}^2}{R_н^2-R_{вн}^2}\cdot\left(1-\frac{R_н^2}{r^2}\right)-\frac{P_oR_н^2}{R_н^2-R_{вн}^2}\cdot\left(1-\frac{R_н^2}{R_{вн}^2}\right)\ ; \qquad (2)$$

The tangential voltage:

$$\sigma_\varphi=-\frac{E_\delta\alpha_\delta}{(1-\nu_\delta)\cdot r^2}\int_{R_{вн}}^{R_н}T(r)rdr+\frac{E_\delta\alpha_\delta}{2(1-\nu_\delta)}\cdot\left(1+\frac{A^2}{r^2}\right)\cdot T_s-\frac{E_\delta\alpha_\delta}{(1-\nu_\delta)}\cdot T(r)+\frac{P^*\cdot R_{вн}^2}{R_н^2-R_{вн}^2}\cdot\left(1+\frac{R_н^2}{r^2}\right)-\frac{P_oR_н^2}{R_н^2-R_{вн}^2}\cdot\left(1+\frac{R_{вн}^2}{R_н^2}\right)\ ;$$

Axial voltage:

$$\sigma_z=E_1\cdot\varepsilon_z-\frac{E_z\alpha_\delta T_1(r)}{(1-\nu_\delta)}+\frac{2\nu_\delta P^*R_{вн}^2}{(R_н^2-R_{вн}^2)}-\frac{2\nu_\delta P_oR_н^2}{(R_н^2-R_{вн}^2)}+\frac{\nu_\delta E_\delta\alpha_\delta}{(1-\nu_\delta)}\cdot T_s$$

Where

$$T_s=\frac{2}{(R_н^2-R_{вн}^2)}\int_{R_{вн}}^{R_н}T(r)rdr$$

Eδ–modulus of material elasticity, respectively, of the cylinder and coating;
T (r)- the temperature changes;
Ts - temperature during plastic region;
Uδ–the movement of the cylinder;
νδ - Poisson's ratio of the material, respectively, of the cylinder and coating.

Let us write the 6 corresponding formulas for coating. For thin-walled cylinder (coating) with the thickness δ, with an outer radius R_{ext}, exposed action of external pressure P * and the uniform temperature To we have

$$\frac{E_c\cdot U_c}{(1+\nu_c)\cdot r}=E_c\alpha_cT_o-\frac{P^*}{\frac{\delta}{R_{вн}}\cdot\left(2-\frac{\delta}{R_{вн}}\right)}\cdot\left[1-2\nu_c+\frac{(R_{вн}-\delta)^2}{r^2}\right]-\frac{E_c\cdot U_c}{(1+\nu_c)}-\frac{E_c\cdot U_c}{(1+\nu_c)}\cdot\varepsilon_z\ ;$$

Radial Voltage:

$$\sigma_r=-\frac{P^*}{\frac{\delta}{R_{вн}}\left(2-\frac{\delta}{R_{вн}}\right)}\cdot\left[1-\left(\frac{R_{вн}-\delta}{r}\right)^2\right] \qquad (3)$$

The tangential voltage:

$$\sigma_o=-\frac{P^*}{\frac{\delta}{R_{вн}}\left(2-\frac{\delta}{R_{вн}}\right)}\cdot\left[1+\left(\frac{R_{вн}-\delta}{r}\right)^2\right];$$

Axial voltage:

$$\sigma_z=E_c\cdot\varepsilon_z-E_c\alpha_cT_o-\frac{2\nu_cP^*}{\frac{\delta}{R_{вн}}\left(2-\frac{\delta}{A}\right)}\ ;$$

νc - Poisson's ratio for the coating material

Herer – varies within

$$1-R_{вн}\le\frac{r}{R_{вн}}\le 1 \qquad (4)$$

When r-R_{inn} and when $\left(\frac{\delta}{R_{вн}}\right)\ll 1$ solution (3) simplifies and takes the form:

$$\frac{E_c\cdot U_c}{R_{вн}(1+\nu_c)}=E_c\alpha_cT_o-P^*\cdot\frac{R_{вн}}{\delta}(1-\nu_c)-\frac{E_c\nu_c\varepsilon_z}{(1+\nu_c)}\ ;$$
$$\sigma_r=0,\sigma_o=-P^*\frac{R_{вн}}{\delta}\ ;$$
$$\sigma_z=E_c\varepsilon_z-E_c\alpha_cT_o-\nu_cP^*\frac{R_{вн}}{\delta} \qquad (5)$$

In formulas (1) and (5) contains two unknowns: P* and εz. These can be determined from conditions:

1) Continuity of radial displacement on the contact surface r =R_{inn}
2) The equilibrium of forces in the axial direction.

From the first condition we will get:

$$(1+\nu_c)[\alpha_cT_o-\alpha_\delta T_o]+[\nu_c-\nu_\delta]=(\nu_c-\nu_\delta)\varepsilon_z-2P_o\cdot\frac{(1-\nu_c^2)R_н^2}{R_н^2(R_н^2-R_{вн})^2}+P^*\left[\frac{(1+\nu_\delta)\left(1-2\nu_\delta+\frac{R_н^2}{R_{вн}^2}\right)}{E_\delta\left(\frac{R_н^2}{R_{вн}^2}-1\right)}+\frac{1-\nu_c^2}{E_c}\cdot\frac{R_{вн}}{\delta}\right];(6)$$

For thin coatings when $\frac{\delta}{R_{вн}}\ll 11$ formula can be simplified:

$$(1+\nu_c)[\alpha_cT_o-\alpha_\delta T_s]+(\nu_c-\nu_\delta)\alpha_\delta T_s=(\nu_c-\nu_\delta)\varepsilon_z+P^*\frac{1-\nu_c^2}{E_c}\cdot\frac{R_{вн}}{\delta}-\frac{2P_o(1-\nu_c^2)}{E_\delta\cdot\left(1-\frac{R_{вн}^2}{R_н^2}\right)} \qquad (7)$$

From the second condition we have

$$\int_{R_{вн-1}}^{R_{вн}} \sigma_z r dr + \int_{R_{вн}}^{R_н} \sigma_z r dr = -\frac{P_o R_н^2}{2} \qquad (8)$$

Substituting the values σzof (1) and (5) we will get

$$E_c\cdot\frac{\delta}{R_{вн}}\cdot[\alpha_c T_o - \alpha_\delta T_s] + \alpha_\delta T_s\cdot\left[\frac{E_c\delta}{R_{вн}} + \frac{E_\delta}{2}\cdot\left(\frac{R_н^2}{R_{вн}^2}-1\right)\right] = P^2(\nu_\delta-\nu_c) + \left[E_c\cdot\frac{t}{A}+\frac{E_\delta}{2}\left(\frac{R_н^2}{R_{вн}^2}+1\right)\right] + P_o \cdot\frac{R_н^2}{2R_{вн}^2}(1-2\nu_\delta) \qquad (9)$$

In the case of coating for which $\frac{\delta}{R_{вн}} \ll 1$we find

$$P^* = \frac{E_c}{(1-\nu_c)}\cdot[\alpha_c T_o - \alpha_\delta T_{s'}]\cdot\frac{\delta}{R_{вн}} + P_o \cdot \frac{(\nu_c-\nu_\delta-2\nu_c\nu_\delta+2)E_c}{\left(1-\frac{R_{вн}^2}{R_н^2}\right)\cdot(1-\nu_c^2)E_\delta\cdot R_{вн}} \qquad (12)$$

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in case of $\nu_\delta = \nu_c$ we will find

$$P^* = \frac{E_c}{(1-\nu_c)}\cdot[\alpha_c T_o-\alpha_\delta T_{s'}]\cdot\frac{\delta}{R_{вн}} + \frac{2E_c P_o}{E_\delta\left(1-\frac{R_{вн}^2}{R_н^2}\right)}\cdot\frac{\delta}{R_{вн}} \qquad (13)$$

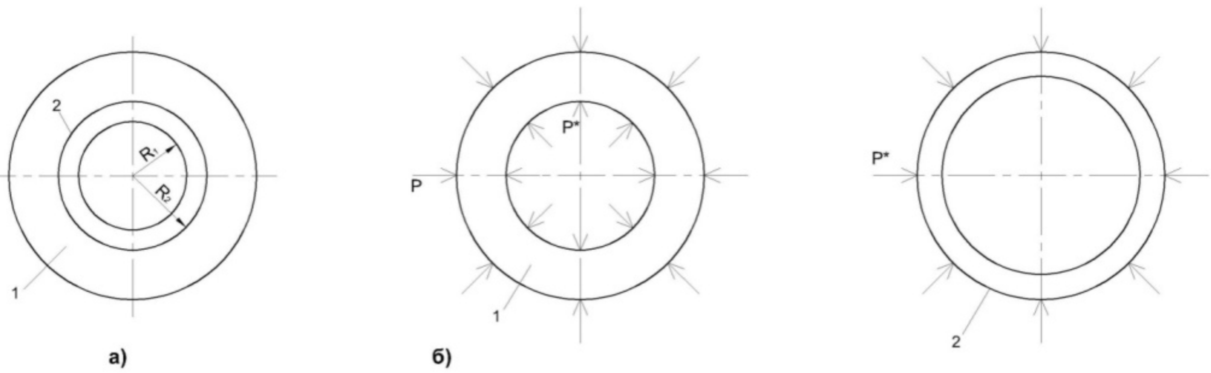

Figure 1. Calculated scheme of the coated cylinder

1-основнойцилиндр; 2-покрытия
1, the basic cylinder; 2-coating

Determining from (9) and (7) and considering that $\frac{\delta}{R_{вн}} \ll 1$,we have

$$\varepsilon_z = \alpha_\delta T_s + \frac{2(1-\nu_\delta)(\alpha_c T_o - \alpha_\delta T_{s'})E_c}{(1-\nu_c)E_\delta\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\cdot\frac{\delta}{R_{вн}} - P_o\cdot\left[\frac{2E_c-(1-\nu_\delta^2)(\nu_\delta-\nu_c)}{E_\delta^2\left(\frac{R_н^2}{R_{вн}^2}-1\right)\left(1-\frac{R_{вн}^2}{R_н^2}\right)(1-\nu_c^2)}\cdot\frac{\delta}{R_{вн}} + \frac{1-2\nu_\delta}{\left(1-\frac{R_{вн}^2}{R_н^2}\right)E_\delta}\right] \qquad (10)$$

As εzis known, using (6), we will define the P *:

$$P^*\left[1+\frac{1+\nu_\delta}{1-\nu_c}\cdot\frac{E_c}{E_\delta}\cdot\frac{\frac{R_н^2}{R_{вн}^2}+1-2\nu_\delta}{\frac{R_н^2}{R_{вн}^2}-1}\cdot\frac{\delta}{R_{вн}}\right] = \frac{\alpha_c T_o-\alpha_s T_s}{1-\nu_c}\cdot\frac{E_c\cdot\delta}{R_{вн}}\cdot\left[1-\frac{(\nu_c-\nu_\delta)(1-\nu_c)E_c\cdot 2}{(1+\nu_c)(1-\nu_c)E_\delta\left(\frac{R_н^2}{R_{вн}^2}-1\right)\cdot R_{вн}}\right] + \frac{P_o E_c\delta}{R_{вн}(1-\nu_c^2)}\cdot\left\{\frac{\nu_c-\nu_\delta-2\nu_c\nu_\delta+2}{E_\delta\left(1-\frac{R_{вн}^2}{R_н^2}\right)} - \frac{2E_c(\nu_\delta-\nu_c)^2\cdot(1-\nu_\delta^2)}{E_\delta^2\left(\frac{R_н^2}{R_{вн}^2}-1\right)\cdot\left(1-\frac{R_{вн}^2}{R_н^2}\right)\cdot(1-\nu_c^2)}\cdot\frac{\delta}{R_{вн}}\right\} \qquad (11)$$

Substituting the expressions εz and P*(10) and (12) in (1), for the voltage component in mainly layer we will get

$$\sigma_r = \frac{E_c\alpha_t}{(1-\nu_\delta)}\cdot\left[-\frac{1}{r^2}\int_{R_{вн}}^{r}T(r)rdr + \left(1+\frac{R_{вн}^2}{r^2}\right)\frac{T_s}{2}\right] + \frac{E_c(\alpha_c T_o-\alpha_\delta T_s)\left(1-\frac{R_н^2}{r^2}\right)}{(1-\nu_c)\cdot\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\cdot\frac{\delta}{R_{вн}} + \frac{P_o}{\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\cdot\left[\frac{\nu_c-\nu_\delta-2\nu_c\nu_\delta+2}{E_\delta\left(1-\frac{R_н^2}{R_{вн}^2}\right)\cdot(1-\nu_c^2)}\cdot\left(1-\frac{R_н^2}{R_{вн}^2}\right)\frac{\delta}{R_{вн}} - \left(\frac{R_н}{R_{вн}}\right)^2\cdot\left(1-\frac{R_{вн}^2}{r^2}\right)\right]$$

$$\sigma_\theta = \frac{E_c\alpha_\delta}{(1-\nu_\delta)}\cdot\left[-\frac{1}{r^2}\int_{R_{вн}}^{R_н} T(r)rdr + \left(1-\frac{R_{вн}^2}{r^2}\right)\frac{T_s}{2}\right] + E_c(\alpha_c T_o - \alpha_\delta T_s)\cdot\left(1-\frac{R_{вн}^2}{r^2}\right)\cdot\frac{T_s}{2} + \frac{E_c\left(\alpha_c T_o - \alpha_\delta T_s\left(1-\frac{R_н^2}{r^2}\right)\right)}{(1-\nu_c)\cdot\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\cdot\frac{\delta}{R_{вн}} + \frac{P_o}{\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\cdot\left[\frac{\nu_c-\nu_\delta-2\nu_c\nu_\delta+2}{E_\delta\left(1-\frac{R_н^2}{R_{вн}^2}\right)\cdot(1-\nu_c^2)}\cdot\left(1-\frac{R_{вн}^2}{R_н^2}\right)\frac{\delta}{R_{вн}} - \left(\frac{R_н}{R_{вн}}\right)^2\cdot\left(1-\frac{R_{вн}^2}{R_н^2}\right)\right]; \qquad (14)$$

$$\sigma_z = \frac{E_c\alpha_\delta}{(1-\nu_\delta)}\cdot[T_{s'} - T(r)] + \frac{2E_c(\alpha_c T_o - \alpha_\delta T_s)}{(1-\nu_c^2)\cdot\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\cdot\frac{\delta}{R_{вн}} - \frac{P_o}{\left(1-\frac{R_{вн}^2}{R_н^2}\right)}\cdot\left[1+\frac{2E_c(1-\nu_c^2)(\nu_\delta-\nu_c)}{E_\delta\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\cdot\frac{\delta}{R_{вн}} - \frac{2\nu_\delta E_c(\nu_c-\nu_\delta-2\nu_c\nu_\delta+2)}{\left(\frac{R_н^2}{R_{вн}^2}-1\right)(1-\nu_c^2)E_\delta}\cdot\frac{\delta}{R_{вн}}\right]$$

Substituting (10) and (12) into (5), we will have:

$$\sigma_r = 0; \qquad \sigma_\theta = -\frac{E_c}{(1-\nu_c)}[\alpha_c T_o - \alpha_\delta T_s] - P_o\cdot\frac{E_c(\nu_c-\nu_\delta-2\nu_c\nu_\delta+2)}{E_\delta\left(1-\frac{R_{вн}^2}{R_н^2}\right)\cdot(1-\nu_c^2)} \qquad (15)$$

$$\sigma_z = -[\alpha_c T_o - \alpha_\delta T_s]\cdot\left[1-2\frac{E_c}{E_\delta}\cdot\frac{(1-\nu_c)}{\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\cdot\frac{\delta}{R_{вн}}\right]\cdot\frac{E_c}{(1-\nu_c)} - \frac{P_o}{\left(1-\frac{R_{вн}^2}{R_н^2}\right)}\cdot\left[\frac{2E_c^2}{E_\delta^2}\cdot\frac{(1-\nu_c^2)(\nu_c-\nu_\delta)}{\left(\frac{R_н^2}{R}-1\right)(1-\nu_c^2)} + \frac{(1-\nu_\delta)E_c}{E_\delta} + \frac{\nu_c(\nu_c-\nu_\delta-2\nu_c\nu_\delta+2)E_c}{E_\delta(1-\nu_c^2)}\right]$$

If $\frac{\delta}{R_{вн}} \ll 1$и$\nu_\delta = \nu_c$,formula (15) takes the form:

$$\sigma_r = 0; \qquad \sigma_\theta = -\frac{E_c}{(1-\nu_c)}[\alpha_c T_o - \alpha_\delta T_s] - \frac{2P_oE_c}{\left(1-\frac{R_{вн}^2}{R_н^2}\right)E_\delta} \qquad (16)$$

$$\sigma_z = -\frac{E_c}{(1-\nu_c)}[\alpha_c T_o - \alpha_\delta T_s] - \frac{P_o}{\left(1-\frac{R_{вн}^2}{R_н^2}\right)}\cdot\frac{E_c}{E_\delta}$$

According to the yield condition of plastic flow begins when

$$K = \max(|\sigma_\theta - \sigma_r|, |\sigma_z - \sigma_r|, |\sigma_\theta - \sigma_z|) = \sigma_T$$

As in the coating $\sigma_r = 0$ according to (16) and (17) flow appears when

$$f = \max\left[-\frac{E_c}{1-\nu_c}[\alpha_\delta T_o - \alpha_\delta T_s] - 2P_o\right]\left|-\frac{E_c}{1-\nu_c}[\alpha_\delta T_o - \alpha_\delta T_s] - P_o\right| = \sigma_T$$

According to (14) and (17) flow in an base layer may begin when performing not less than one of three conditions:

$$(\sigma_\theta - \sigma_r) = \frac{E_\delta\alpha_\delta}{(1-\nu)}\left[\frac{2}{r^2}\cdot\int_{R_{вн}}^{r} T(r)rdr + \frac{R_{вн}^2}{r^2}\cdot T_S - T(r)\right] + \frac{2E_c(\alpha_c T_o - \alpha_\delta T_s)R_н^2}{(1-\nu)\cdot\left(\frac{R_н^2}{R_{вн}^2}-1\right)r^2}\cdot\frac{\delta}{R_{вн}} + P_o\left(\frac{4E_c}{E_\delta}\cdot\frac{\frac{R_н^2}{r^2}}{1-\frac{R_{вн}^2}{R_н^2}}\cdot\frac{\delta}{R_{вн}} - \frac{R_н^2}{r^2}\cdot\frac{R_{вн}^2}{r^2}\right) = \pm\sigma_{тек\ \delta} \qquad (17)$$

$$(\sigma_z - \sigma_r) = \frac{E_\delta\alpha_\delta}{(1-\nu)}\left[\frac{1}{r^2}\cdot\int_{R_{вн}}^{r} T(r)rdr + \left(\frac{R_{вн}^2}{R_н^2} + \left(\frac{R_{вн}^2}{R_н^2}+1\right)\frac{T_S}{2}\right) - T(r)\right] + \frac{E_c(\alpha_c T_o - \alpha_\delta T_s)}{(1-\nu)\cdot\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\left(\frac{R_н^2}{R_{вн}^2}+1\right)\cdot\frac{\delta}{R_{вн}} + P_o\left[-\frac{4\nu E_c}{E_\delta\left(1-\frac{R_{вн}^2}{R_н^2}\right)}\cdot\frac{\delta}{R_{вн}} - \frac{2E_c\left(1-\frac{R_н^2}{r^2}\right)}{E_\delta\left(1-\frac{R_{вн}^2}{R_н^2}\right)}\cdot\frac{\delta}{R_{вн}} + \frac{2R_н^2}{R_{вн}^2} - \frac{R_н^2}{r^2}\right] = \pm\sigma_{тек\ \delta}$$

Или

or

$$(\sigma_\theta - \sigma_z) = \frac{E_\delta\alpha_\delta}{(1-\nu)}\left[\frac{1}{r^2}\cdot\int_{R_{вн}}^{r} T(r)rdr + \left(\frac{R_{вн}^2}{r^2}-1\right)\cdot\frac{T_S}{2}\right] + \frac{E_c(\alpha_c T_o - \alpha_\delta T_s)}{(1-\nu)\cdot\left(\frac{R_н^2}{R_{вн}^2}-1\right)}\left(\frac{R_н^2}{r^2}-1\right)\cdot\frac{\delta}{R_{вн}} + P_o\left[\frac{2E_c}{E_\delta\left(1-\frac{R_{вн}^2}{R_н^2}\right)}\cdot\frac{\delta}{R_{вн}}\cdot\left(1-2\nu+\frac{R_н^2}{R_{вн}^2}\right) - \frac{R_н^2}{R_{вн}^2}\cdot\left(1+\frac{R_{вн}^2}{r^2}\right) + \frac{R_н^2}{R_{вн}^2}\right] = \pm\sigma_{тек\ \delta}$$

Conclusion

In the first plastic flow can arise in an either the base layer or the coating depending on the nature of the temperature distribution and material properties.

REFERENCES

Kupradze V.D., Hegelia T.G. Basheeleyshvili M.O., T.V. Burchuladze, 1976. Three-dimensional problems of the mathematical theory of elasticity and thermoelasticity. Classical and micropolar theory. Statics harmonics, dynamics basics and methods of solution. The second, revised and supplemented. published. By editing. Kupradze V.D.M., Science, published 663 p

Mammadov, V.T. 1997. The calculation and design basics of leaktightnessnodes elastic elements of the oil-field equipment Baku: Science, 461, ISBN 5-8066-07-19-6.

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